DOCUMENT RESUME

ED 174 101 HE 011 442

AUTHOR Carney, Paul
TITLE Multivariate Analysis in Institutional Research. AIR Forum 1979 Paper.
PUB DATE May 79
NOTE 35p.; Paper presented at the Annual Forum of the Association for Institutional Research (19th, San Diego, California, May 13-17, 1979)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Analysis of Variance; *Data Analysis; *Discriminant Analysis; Factor Analysis; Higher Education; *Institutional Research; *Research Methodology; Resource Allocations; *Statistical Analysis; Theories
IDENTIFIERS AIR Forum 1979

ABSTRACT

This introduction to the theory and application of multivariate analysis is designed to assist institutional researchers who are interested in using these techniques to analyze issues within their respective institutions. A brief introduction to multivariate theory, consisting of a rationale for multivariate statistics and an overview of selected multivariate techniques, is presented. Applications of multivariate analysis in institutional research, obtained from a review of the literature in the field, are discussed, with particular emphasis given to studies because of their utilization of intrainstitutional, rather than interinstitutional data. The studies described used a variety of multivariate statistical procedures, including multivariate analysis of variance, discriminant analysis, canonical correlation, and factor analysis. Possible applications are suggested in the traditional institutional research areas of students, faculty, academic programs, resource allocation, and institutional evaluation. Additional potential applications of multivariate analysis in institutional research are also suggested, including using discriminant analysis as a classification technique. (SC)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED174101

THE ASSOCIATION FOR INSTITUTIONAL RESEARCH

This paper was presented at the Nineteenth Annual Forum of the Association for Institutional Research held at the Town and Country Inn in San Diego, California, May 13-17, 1979. This paper was reviewed by the AIR Forum Publications Committee and was judged to be of high quality and of interest to others concerned with the research of higher education. It has therefore been selected to be included in the ERIC collection of Forum papers.

Mary Corcoran
University of Minnesota
(Editor, AIR Forum Publications)

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

AIR

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

NE 011 442

Multivariate Analysis
in
Institutional Research

Paul Carney
Office of Budget and Analysis
Florida State University
Room 424 Westcott
Tallahassee, Florida 32306
(904) 644-4203

Abstract

The purpose of this paper is to provide institutional researchers with an introduction to the theory and application of multivariate analysis in the field. A brief discussion of multivariate theory, consisting of a rationale for multivariate statistics and an overview of selected multivariate techniques, is presented. Applications of multivariate analysis in institutional research, obtained from a review of the literature in the field, are discussed; with particular emphasis given to studies because of their utilization of intra- rather than inter- institutional data. Additional applications of multivariate analysis in institutional research are also suggested by the author. The purpose of this discussion is to help institutional researchers see the possibilities of using multivariate techniques in analyzing issues pertinent to their institutions and to encourage the increased use of multivariate analysis in appropriate institutional research settings.

Multivariate Analysis in Institutional Research

Introduction and Purpose

As multivariate statistical methods become increasingly available and the large masses of data gathered by post-secondary institutions are more readily accessed, the opportunity for institutional researchers to apply multivariate analysis to issues in the field is rapidly becoming apparent. The purpose of this paper is to assist institutional researchers who are interested in using multivariate techniques to analyze issues within their respective institutions. A brief introduction to multivariate analysis, consisting of a rationale for multivariate statistics and an overview of selected multivariate techniques, is presented. A review of the literature in the field provided numerous examples of multivariate analysis in institutional research, with particular emphasis given to studies because of their utilization of intra- rather than inter- institutional data. Possible applications are suggested in the traditional institutional research areas of students, faculty, academic programs, resource allocation and institutional evaluation. The paper concludes with a discussion of additional applications of multivariate analysis in institutional research suggested by the author. The purpose of this discussion is to help institutional researchers see the possibilities of using multivariate techniques in analyzing issues pertinent to their institutions and to encourage the increased use of multivariate analysis in appropriate institutional research settings.

A Rationale for Multivariate Statistics

The studies described in this paper used a variety of multivariate statistical procedures including multivariate analysis of variance, discriminant analysis, canonical correlation and factor analysis. It should be noted that the term multivariate statistics can be applied to an assortment of descriptive and inferential techniques that have been developed to handle situations where sets of variables are involved either as predictors or as measures of performance. For the purpose of this research, however, the definition of multivariate statistics will include only those techniques that can be applied to situations involving multiple dependent measures. (In factor analysis and other related techniques, of course, the distinction between independent and dependent variables is irrelevant because only one set of variables is involved.) Although this definition excludes such techniques as analysis of variance and multiple regression, in the opinion of the author it more clearly delineates the statistical procedures commonly referred to as multivariate statistics and prevents the repetition of material that is available in many excellent texts in the behavioral sciences (e.g., Winer, 1971; Kerlinger and Pedhazur, 1973) and has been widely applied in institutional research.

According to Harris (1975), multivariate statistical techniques perform essentially two general functions, corresponding roughly to the distinction between descriptive and inferential

statistics. On the descriptive side, these procedures provide rules for combining the variables in an optimal way. (These "optimal" combinations vary from one technique to the next and will be made explicit in the next section.) On the inferential side, multivariate statistics provide a solution to the multiple comparison problem. Almost any situation in which multivariate techniques are applied could be analyzed through a series of univariate tests of significance, one such univariate test for each possible combination of one of the independent variables with one of the dependent variables. However, when multiple univariate tests are employed (just as in the case of multiple t-tests vs. analysis of variance), the probability of having at least one of the tests produce a significant result when in fact nothing but chance variation is taking place, increases rapidly as the number of tests increases. Consequently, it is highly desirable to have a means of controlling error rate over several related tests. By combining the individual univariate hypotheses into a single multivariate hypothesis, multivariate statistical techniques provide this control. They also, in many cases, provide for post hoc comparisons which explore the statistical significance of various possible explanations of the overall statistical significance of the relationship between the independent and dependent variables.

An important difference between the descriptive and inferential uses of multivariate techniques is that the former require no assumptions about the distributions from which the observations

are sampled, while most of the multivariate tests of significance, like their univariate counterparts, are based on homogeneity and normality assumptions. It is well known that the common univariate tests are generally quite robust (i.e., insensitive to any but extreme departures from normality and homogeneity assumptions. Less is known about the robustness of the corresponding multivariate techniques but, as Harris (1975) states, the evidence so far suggests a similar degree of robustness.

An Overview of Selected Multivariate Techniques

Although a multivariate counterpart exists for almost every univariate test of significance, for the purpose of this research four multivariate techniques (viz., multivariate analysis of variance, discriminant analysis, canonical correlation and factor analysis) are selected for discussion. The descriptions of these techniques are meant to acquaint institutional researchers with the variety of multivariate procedures available and to provide those unfamiliar with multivariate analysis with a working understanding of the basic concepts of these techniques without being inundated with statistical details. The emphasis here is toward providing institutional researchers with a general orientation to these procedures rather than an exhaustive statistical treatment of each technique. For a more extensive discussion of particular multivariate techniques and their mathematical derivations the reader should consult the presentations made by Harris (1975), Kim (1975), Klecka (1975), Tatsuoka (1971), and Warwick (1975).

Multivariate Analysis of Variance

Multivariate analysis of variance provides generalization of the univariate analysis of variance. This technique is applicable whenever there are several groups of subjects, with more than one measure of performance being obtained on each subject. The test of the overall null hypothesis is accomplished by reducing the set of outcome measures on each subject to a single number by the simple process of multiplying the subject's score on each of the original variables by a weight associated with that variable and then adding these products together. A univariate F-ratio based on the overall difference between the group means on the combined variable is then computed. A second set of weights which may produce a larger F-ratio is tried out, and this process is continued until that linear combination which makes the univariate F-ratio on the combined variable as large as it can possibly be has been found. (Computationally, of course, this solution is arrived at through the use of matrix algebra and calculus.) This optimal linear combination -- optimal in the sense that it maximally discriminates between the groups -- is called the discriminant function, and the largest possible F-value is the basis for the significance test of the overall null hypothesis.

Discriminant Analysis

After one of the multivariate procedures for testing the significance of the overall difference among several group means has been computed and a significant difference has been found,

the question still remains of just how the groups differ in terms of the dependent variables. Discriminant analysis is a multivariate technique which attempts to answer this question by identifying the directions or dimensions along which the group differ most conspicuously. The mathematical objective of discriminant analysis is to weight and linearly combine the original dependent variables in the same fashion so that the groups are forced to be as statistically distinct as possible. In other words, the goal of discriminant analysis is to "discriminate" between the groups in the sense of being able to tell them apart. By taking several variables and mathematically combining them, the researcher would hope to find a single dimension on which the groups are separated (statistically) as much as possible. Discriminant analysis attempts to do this by forming one or more linear combinations of the original dependent variables.

Once the discriminant functions have been derived the researcher is able to pursue the two research objectives of this technique: analysis and classification. The analysis aspects of discriminant analysis provide several tools for the interpretation of data. When there are more than two groups, it may be possible to obtain satisfactory discrimination with fewer than the maximum number of functions. (The maximum number of discriminant functions which can be derived is either one less than the number of groups or equal to the number of dependent variables, if there are more groups than variables.) The result is often theoretically significant and statistical tests are

included for this purpose. Another important component of discriminant analysis is that the weighting coefficients can be interpreted much as in multiple regression or factor analysis. In this respect, they serve to identify the dependent variables which contribute most to differentiation along the respective dimension (function).

The use of discriminant analysis as a classification technique comes after the initial computation. Once a set of variables is found which provide satisfactory discrimination for cases with known group membership, a set of classification functions can be derived which will permit the classification of new cases with unknown memberships. This classification procedure involves the use of a separate linear combination of the dependent variables for each group. These combinations produce a probability of membership in the respective group, and the case is assigned to the group with the highest probability.

Canonical Correlation.

Canonical correlation takes as its basic input two sets of variables, each of which can be given theoretical meaning as a set. The basic goal of canonical correlation analysis is to derive a linear combination from each of the sets of variables in such a way that the correlation between the two linear combinations is maximized. These canonical variates, as they are known, are produced for the purpose of accounting for a maximum amount of the relationship between the two sets of variables. The first pair of canonical variates are selected so as to have the highest

intercorrelation possible, given the particular variables involved. Because each successive canonical variate is selected on the basis of the residual variance accounted for (variance the preceding variates could not account for), it produces linear combinations of variables that are independent or uncorrelated with one another. Although this is sometimes helpful it may also, at least partially, distort the data (see Warwick, 1975).

The two most imp rtant types of information produced by canonical correlation analysis are the canonical variates and the canonical correlations between them. The canonical variates come in two sets, one for each of the subsets of variables entered into the analysis. These variates are composed of coefficients that reflect the importance of the original variables in the subset in forming the variates. The essential point to canonical correlation is that the canonical variates are chosen to maximally correlate with each other, for the first and all successive pairs of canonical variates. The amount of correlation between each corresponding pair of canonical variates is the canonical correlation between them, and its square (the eigenvalue) represents the amount of variance in one canonical variate that is accounted for by the other canonical variate.

Factor Analysis

The statistical techniques discussed so far all involve relationships between sets of variables. Factor analysis, on the other hand, concentrates on relationships within a single set of variables. Given an array of correlation coefficients

for a set of variables, factor-analytic techniques can be used to determine whether some underlying pattern of relationships exists such that the data may be "rearranged" or "reduced" to a small set of factors or components with as little loss of information as possible.

According to Kim (1975), the term factor analysis can be applied to a fairly wide variety of statistical procedures, most of which involve three major steps: 1) the preparation of the correlation matrix, 2) the extraction of the initial factors -- the exploration of possible data reduction, and 3) the rotation to a terminal solution -- the search for simple and interpretable factors.

The first step in factor analysis involves the selection of a set of relevant variables and the calculation of appropriate measures of association. It is mandatory that the researcher define the relevant area of analysis. The nature and scope of the variables included in the analysis have crucial implications for the factor results and their interpretation. In addition, given that some type of correlation matrix is used as the basic input in factor analysis, the researcher has some alternatives: correlations between individuals or objects (Q-type factor analysis) or correlations between variables or attributes (R-type factor analysis) may be utilized.

The second step in factor analysis is to explore the possibilities of reducing the data by constructing a set of new variables on the basis of the interrelations found in the data.

In doing so, the new variables may be defined as exact mathematical transformations of the original data (principal components analysis), or assumptions may be made about the structuring of variables and their sources of variation (classical-factor analysis). Principal components analysis is a relatively straightforward way of transforming a given set of variables into a new set of composite variables or principal components that are orthogonal (uncorrelated) to each other. Classical-factor analysis, on the other hand assumes that the total variation in the data can be separated into unique variance (variance that can be attributed to influences that have nothing to do with the other variables in the set) and common variance. Under the assumption, the unique variance does not contribute to relationships among variables. Therefore, if there is any correlation between the variables, it is assumed to be due to the common factors.

The final step in factor analysis is the rotation to a terminal solution -- the search for simple and interpretable factors. It must be remembered that in almost all methods of factor analysis the solution is not unique, that is, there are many statistically equivalent ways to define the underlying structure of the same set of data. Therefore, the researcher is left to choose the best rotational method to arrive at a terminal solution that satisfies the theoretical and practical needs of the research problem. The major option is whether to choose an orthogonal rotational method or an oblique rotational method. (Orthogonal factors are uncorrelated, while oblique factors may be correlated.) The basic reason

for employing any rotational method is the same: to achieve simpler and theoretically more meaningful factor patterns. Orthogonal factors are mathematically simpler to handle, while the oblique factors are empirically more realistic. There is no reason to favor one method over another, and the choice should be made on the basis of the particular needs of a given research problem.

A Review of the literature

A comprehensive review of the three major publications in the field provided the examples of multivariate analysis in institutional research included in this review. Studies were selected from the Proceedings of the Annual Forum of the Association for Institutional Research (1963-1977), the New Directions for Institutional Research (1974-1978, Vols. 1-5), and Research in Higher Education (1973-1978, Vols. 1-8). Of the more than 500 entries in these sources, approximately 60 studies were found to have employed multivariate techniques, as defined in this research, in their analysis of data. These studies were then examined for their utilization of intra-institutional data and their relevance to institutional researchers. Through this process, 15 studies were selected for extensive examination in this review. As previously noted, the categories used to classify these studies were the traditional institutional research areas: students, faculty, academic programs, resource allocation and institutional evaluation.

Students

In the student area of institutional research activity, four studies were found in the literature which satisfied the criteria presented for inclusion in this review. It is interesting that of the four studies examined here, all four were concerned with a single issue (i.e. student attrition and retention) and three of these studies were conducted by the same authors.

In the first of a series of three studies which investigated (in an increasingly-focused manner) the problem of student attrition and retention, Pascarella and Terenzini (1976) sought to determine the extent to which students who frequently engaged in informal interaction with faculty beyond the classroom differed from those who did not, in terms of their rating of the academic program and of nonacademic life, and in terms of their rate of attrition. Students' perceptions of their academic programs and their non-academic lives, along with each student's reported participation in extracurricular activities and cumulative freshman GPA served as the dependent measures in the analysis. Multivariate analysis of variance performed on these variables indicated the presence of overall significant differences among the three group mean vectors. (Students were divided into three groups: low, moderate and high interactors according to the number of informal interactions with faculty that they reported on a questionnaire.) Discriminant analysis determine that high and moderate interactor groups in the study were best differentiated from low interactors on the basis of their more positive ratings of their academic program on interest

value and practical appeal factors and their more positive ratings of their nonacademic lives on the interest value dimension. Additional analyses found that the rate of attrition among low interactors was more than twice as high as the percentage among moderate interactors and more than three times as high as the percentage among high interactors.

In the second study of the series, Terenzini and Pascarella (1976) assessed the validity of Tinto's theory of student attrition, which asserts that withdrawal relates most directly to students' integration in the social and academic systems of an institution. This study focused on the differences between students who continued their enrollment into their sophomore year and those who voluntarily withdrew at the end of their freshman year. The study examined these two groups in terms of two sets of variables: variables representing students' academic integration (including students' perceptions of their academic program and each student's cumulative first-year GPA) and those representing students' social integration (including students' perceptions of their nonacademic life, the number of extracurricular activities participated in which students reported participation, and the number of times students reported interacting informally with faculty members outside of class for ten minutes or more). Separate multivariate analysis of variance of the academic and social integration variable sets indicated that each set, independent of the other, was able to differentiate significantly between groups of stayers

and voluntary leavers. Consistent with Tinto's theory, stayers had significantly more positive perceptions than leavers of both their academic programs and their nonacademic lives. Discriminant analysis suggested, when the two variable sets were combined, that the joint contribution of the two sets were approximately equal, tending to support Tinto's assertion of the relative importance of these two constructs.

The third study of the series Terenzini and Pascarella (1977a) updated the previous research and sought to improve upon that research by taking into account certain possible initial differences between students who withdrew voluntarily after one year and those who did not. A multivariate analysis of variance done with respect to students's initial attributes and expectations (i.e., academic aptitude, personality characteristics, prematriculation expectations of their academic programs and nonacademic lives, expected number of informal contacts with faculty, and the number of extracurricular activities in which the students would engage) resulted in a non-significant F-ratio, indicating no differences between the groups with respect to the initial characteristics. The authors concluded that the findings of this study suggested that what happens to a student after he or she matriculates may have at least as great an influence (if not a greater influence) on subsequent attrition-related decisions as initial expectations, personality characteristics, or academic aptitude. In addition, a stepwise discriminant analysis of thirteen post-registration variables (residualized on students'

initial characteristics and expectations) indicated that, contrary to Tinto's theory, academic variables were more important than social variables in students' decisions to remain or withdraw voluntarily. Stayers reported both more emotional attractiveness and less dullness in their academic programs than leavers. These two variables were followed closely in importance by a respondent's confidence that his or her decision to attend the university was a good one and by the amount of reported informal contact with faculty members outside the classroom.

Morgan (1974) used stepwise descriminant analysis to determine how certain cognitive and non-cognitive variables related to male university attrition. Ability and personality test scores of 256 randomly selected males were analyzed, with six classifications of college persistence (identified seven semesters after matriculation) serving as the dependent variables. The most powerful discriminator was overall ability, with authoritarianism, natural science ability and nonconformity also contributing to discrimination. Analysis of group means indicated: a) the most able, most autonomous group included those who withdrew; and b) the students who seemed most likely to graduate in four years (seniors seven semesters after matriculation) were the most authoritarian and among the most conforming of the groups studied.

Faculty

Four studies were found in the literature which satisfied the criteria presented for inclusion in this section of the review. In a study conducted by Madron, Craig and Mendel (1976), an

attempt was made to identify some of the factors significantly related to the morale in university departments. Initially, a total of 11 characteristics or attributes were identified for use in evaluating departmental morale. Discriminant analysis was then performed on departmentally aggregated data to test the importance of these variables in the prediction of morale. Results indicated that departmental size and the perceived performance of department heads (among others) were important in predicting levels of morale in a university department.

Smart and Elton (1976) used multivariate analysis to assess the specific differences in how chairmen in eight clusters of academic departments (identified by Biglan in his three-dimensional model) devote their time to a wide range of professional responsibilities. A factor analysis of the time spent on 27 duties typically performed by department chairmen identified four orthogonally-rotated factors. The pattern of loadings on these factors suggested the titles of four administrative roles. The reliability of Biglan's model was assessed by plotting the eight group centroids on the three statistically significant discriminant functions produced by a discriminant analysis of these factors. The clustering of the academic department chairman on the three discriminant functions was generally consistent with Biglan's model. The results of discriminant analysis also indicated that all of the significant variance among the eight groups was accounted for by three of the four administrative roles: research, instructional and faculty supervision. Additional

analysis of the group means indicated that the amount of time devoted to these administrative roles provided significant differences in 23 of the 28 possible comparisons or chairmen in the eight groups of academic departments.

In another type of faculty study, commonly conducted by institutional researchers, Hesseldenz (1976) used multivariate analysis in an examination of faculty workload. This study classified faculty members according to personality type (using Holland's theory of vocational choice) and their academic rank. Four self-reported measures of faculty effort: instruction, research, public service, and institutional-professional activities (all measured in hours per average week) served as the dependent variables in this analysis. A non-orthogonal, two-way multivariate analysis of variance indicated that while there was no significant multivariate interaction, the main effects of personality type and rank were significant. Faculty members of the five Holland types not only differed on the dependent measures but the differences were, in general, supportive of Holland's theory. In addition, analysis by rank showed that while total hours per week were not statistically different among the ranks, hours in instructional and institutional-professional activities varied greatly yet hours in research and public service did not. The author concluded that changes in instructional workload will not affect research or public service activities of faculty members.

In a study relating to the same topic, Creswell (1978) asked faculty members at a large midwestern state university how they

felt about the workload survey administered on campus and whether four variables (suggested by an NCHEMS report) were related to their acceptance of the survey. Factor analysis, multiple regression, and path analysis were used to analyze faculty responses to a questionnaire (developed by the author) that operationalized the four NCHEMS' factors as the independent variables and faculty acceptance as the dependent variable. Results upheld one of the four NCHEMS relationships, namely, that a positive attitude toward a workload survey is related to the perceived value of the data at the departmental level.

Academic Programs

The evaluation of academic programs is an area of institutional research that is rapidly receiving increased attention both from internal and external sources. One of the most important tasks in the evaluation of academic programs, the development of criteria utilized in the evaluation process, is the subject of a study conducted by Perry and Lind (1976). The responses of 140 department chairpersons and 272 graduates to a list of 33 criterion statements thought to be useful in program evaluation were examined through factor analysis. This analysis identified nine interpretable factors which explained slightly less than 60 percent of the variability within the 33 criterion statements. Factor scores computed for each respondent on each factor were used to test various hypotheses of interest. For example, when the nine mean factor scores for department chairpersons and graduates were compared, it was found that department chairpersons viewed the

factors of program size, supportive nature of the program, and nonteaching work of the faculty significantly more important than did the graduates. Graduate students, on the other hand, viewed the factors of academic standards, cost efficiency, innovative programs, employability, and public relations as significantly more important than did the department chairpersons.

Another important issue in the area of academic program evaluation is the evaluation of the innovative programs. In the process of evaluating an "innovation" the Pass/Not Pass grading option at the University of California at Berkeley -- Bess and Hayes (1971) developed a research model which could possibly serve as the basis for evaluating other educational innovations. Three "subcultures" of students ("academic", "vocational", and "expressive") with similiar personality characteristics, value orientations, educational goals and behaviors were identified through factor analysis of student responses to a questionnaire. The factor scores of students in these subcultures were then correlated with their ratings of experiences in courses which exercised the Pass/Not Pass grading option. By correlating the effects of this innovation with membership in the subcultures, it was possible to determine that: 1) the reasons for students selecting Pass/Not Pass grading differed among subcultures; 2) certain portions of the student population seem to benefit from this experience more than others; and 3) attitudes toward the continuation or extension of the Pass/Not Pass grading option differed for students within the respective subcultures. After

comparing these results with an evaluation which classified students into traditional demographic categories, the authors concluded that student subcultures, rather than traditional classifications, provided more interesting and more specific information in understanding the educational benefits of this innovation.

Resource Allocation

Due to inflation and increasingly austere appropriations for higher education, many institutional researchers have recently found themselves faced with the responsibility of evaluating the resource allocation process and its impact within their respective institutions much more closely than in the past. In the first of two studies included in this section, Hoyt and Stewart (1976) used multivariate analysis to examine the relationships between faculty accomplishments and faculty rewards. Principal component analyses of 161 faculty responses determined that 12 reward measures and 36 measures of faculty accomplishment could be adequately represented by five and nine factors, respectively. Factor coefficients were then used to compute factor scores for each of the 161 faculty members included in the study. Using the male sample data, multiple regression analyses indicated that three reward factor scores could be predicted on the basis of the accomplishment factor scores. The male regression equations were then applied to female accomplishment data and discrepancy scores were computed by subtracting each subject's actual reward status from status predicted on the basis of accomplishment.

Mean discrepancy scores for the two sexes were then compared for significant differences. By definition, the mean discrepancy score for males was 0.00 on all criteria. For females all three means were negative, that is, average reward scores were below predicted reward scores. However, the difference was significant only in the case of the monetary factor, where rewards averaged almost half a standard deviation below prediction. The authors concluded that, in the area of monetary rewards, the charge of sex discrimination appeared to be upheld.

While Hoyt and Stewart examined the resource allocation process within an institution, Girves (1976) studied the impact that funding from outside the institution (in this case, the federal government) had on a university's graduate programs. The study focused on the relationship between shifts in federal funding patterns for university research and shifts in graduate education and research conducted within 55 departments between 1969 and 1974 in a large midwestern university. Canonical correlations between the set of seven federal funding variables and each of five subsets of 34 graduate education and research variables were computed for the two fiscal years and for the changes occurring between them. Results indicated that shifts in federal funding were most strongly associated with changes in 12 institutional variables. Approximately 42 percent of the variability among these graduate education and research variables was accounted for by the federal funded variables. In general, those departments that experienced decreased involvement

in federally funded research tended to experience: 1) a decline in the number of research associates and federally supported graduate students with an increase in the number of teaching associates; 2) an increase in university funding; and 3) a decrease in enrollment with more students enrolling part-time.

Institutional Evaluation

One of the major responsibilities of an institutional research office is the evaluation of a particular institution in terms of its goals and objectives. This section contains three studies in which institutional researchers have used multivariate statistics in this type of analysis. Smart (1975) used multivariate analysis to compare the institutional goal preferences of students, faculty and administrators at a large eastern state college. Responses of 804 students, faculty and administrators to 47 institutional goal statements developed by Gross and Grambsh were factor analyzed and five types of institutional goals were identified for use in further analysis. Using the factor scores of the five types of institutional goals as predictor variables, a multiple discriminant analysis indicated that all five types of institutional goals contributed significantly to the discrimination between the three groups included in the sample. Further investigation disclosed that while students differed significantly from both faculty and administrators in all five of the institutional goal categories, faculty and administrators did not differ significantly on any of the five types of institutional goals. The author concluded that

the disagreement over goals between students, faculty and administrators found in this study might reflect a more deep-seated value conflict between these groups; and that faculty and administrators must begin to take seriously student goals as they develop their educational programs.

A study by Biggs, Brown and Kingston (1977) used multivariate analysis to examine the relationship between citizens' educational values and satisfaction with the University of Minnesota. Factor analysis was utilized to identify categories of educational values in three areas: 1) the importance of various educational goals and activities, 2) the importance of various academic areas and disciplines, and 3) the importance of various reasons for attending the university. Multiple regression procedures were then used to examine the relationship between the three sets of educational values and the dependent variable, satisfaction with the university. Results of these analyses indicated that while citizens' values regarding important goals and activities of the university and their values regarding important reasons for attending the university were somewhat related to their satisfaction; a large amount of the variance in citizen satisfaction was still not explained. Although the results of this study were not conclusive, the authors suggested that this type of systematic assessment of citizens' opinions on issues facing public higher education can provide extremely useful information for institutional decision making.

The third study included in this section of the review involved a somewhat more formal type of institutional evaluation. The

primary purpose of this study, conducted by Krus, Weidman and Bland (1975), was to describe the Semiprojective Scales of Institutional Evaluation (SSIE) and investigate some commonly expressed concerns regarding student preceptions of a large university. Four SSIE scales, measuring positive and negative connations of an educational institution, were developed by order analysis. This multivariate technique, proposed by Krus as an inferential alternative to factor analysis, allows for "gradation of sensitivity with respect to underlying dimensions of the data matrix". Four separate multiple regressions were then computed to determine the relationships between ten predictor scales (measuring students' personal and organizational orientations) and the four SSIE scales. The interrelations between these measures suggested that favorable images of the college environment were likely to result when the institution: 1) provides a balance of general knowledge and specific skills; 2) permits students to participate in setting their own educational goals; and 3) promotes programs that take into account individual differences in the academic abilities of the students involved.

Additional Multivariate Applications

In addition to the examples of multivariate analysis provided by the literature, the author would like to suggest three other multivariate applications which would seem to be particularly useful to institutional researchers. Hopefully, these applications not only will provide the reader with additional examples of

multivariate analysis in institutional research, but will help institutional researchers to see the possibilities of using multivariate techniques in analyzing issues within their respective institutions.

First of all, the author would suggest that institutional researchers explore the possibilities of using multivariate multiple regression (MMR) in appropriate institutional research settings. By taking into account multiple dependent variables as well as multiple independent variables, MMR combines the descriptive and inferential functions performed by all multivariate techniques with the advantages and applicability of multiple regression. It is suggested that this type of statistical analysis would be very useful in a wide range of institutional research settings. For example, the study by Pascarella and Terenzini (1976) included in the literature review (see p.12) might have been conducted using MMR rather than multivariate analysis of variance. Because MMR has the ability to handle continuous independent variables, the researchers would not have found it necessary to classify students into high, moderate and low interaction categories. Thus, the utilization of MMR would have prevented the loss of information and provided a more complete analysis of the data.

The use of discriminant analysis as a classification technique is another multivariate application which would seem to be particularly useful in institutional research. Consider, for example, the area of projecting student enrollment. If a set of variables could be identified which satisfactorily discriminated between

students who enrolled at a university and those who did not, discriminant analysis could be used to produce a set of classification functions that would provide an enrollment probability for each student. An institutional researcher could then project student enrollment by assigning each prospective student to a particular enrollment category based upon the probability of enrollment for that student. In addition to improving enrollment projections, this approach would also identify groups of students with low enrollment probabilities. This information would be particularly useful in the design and implementation of student recruitment programs.

Finally, the author would suggest that institutional researchers consider the possibilities of using multivariate analysis to improve the process of allocating resources among university departments. Dressel and Simon (1976) for example, used factor analysis and multiple-discriminant analysis in an attempt to identify "clusters" of departments with similar characteristics and missions within a university. Although the results of this study were inconclusive, it did identify an interesting methodology that would warrant further investigation by institutional researchers. If the appropriate variables could be identified, discriminant analysis and factor analytic techniques could be used to separate departments into units that would utilize the same funding principles and criteria. Each department would then be compared with other departments in its

unit and not with every department in the institution. This approach would permit variability among departmental units while stressing uniform-funding criteria within units.

Concluding Remarks

The information presented in this paper provides the reader with a brief introduction to multivariate analysis and its applicability in institutional research. Institutional researchers are encouraged to consider multivariate analysis as an appropriate statistical alternative in the field and to employ it when the institutional research problem, the theory behind the problem and the limitations of the data justify its use.

In closing, the author would suggest that by properly applying multivariate analysis in appropriate institutional research settings, institutional researchers are able to study the complex issues of higher education in greater depth thereby providing improved information for institutional decision-making.

References

Bess, J. L., and Hayes, C. Benefits and beneficiaries of innovations: A research model. Proceedings of the 11th Annual Forum of the Association for Institutional Research, 1971, 43-47.

Biggs, D. A., Brown, J., and Kingston, G. Citizens' educational values and their satisfaction with a state university. Research in Higher Education, 1977, 6, 157-167.

Creswell, J. W. Faculty acceptance of a workload survey in one major university. Research in Higher Education, 1978, 8, 205-226.

Dressel, P. L., and Simon, L. A. Allocating resources among departments. New Directions for Institutional Research (No. 11). San Francisco: Jossey-Bass, 1976, 43-59.

Girves, J. E. The impact of federal funding of university research on graduate education and research. Proceedings of the 17th Annual Forum of the Association for Institutional Research. 1978, 73-76.

Harris, R. J. A Primer of Multivariate Statistics. New York: Academic Press, 1975.

Hesseldenz, J. S. Personality-based faculty workload analysis. Research in Higher Education, 1976, 5, 321-334.

Hoyt, D. P. and Stewart, M. O. Faculty rewards, faculty accomplishments and sex discrimination. Proceedings of the 16th Annual Forum of the Association for Institutional Research, 1976, 183-187.

Kerlinger, F. N. and Pedlazur, E. J. Multiple Regression in Behavioral Research. New York: Holt, Rinehart and Winston, 1973.

Kim, J. Factor Analysis. In N. Nie, C. Hull, J. Jenkins, K. Steinbrenner, and D. Bent, SPSS: Statistical Package for the Social Sciences (2nd ed.). New York: McGraw, 1975.

Klecka, W. R. Discriminant analysis. In N. Nie et al, SPSS: Statistical Package for the Social Sciences (2nd ed.). New York: McGraw-Hill, 1975.

Krus, D. J., Weidman, J. C., and Bland, P. C. SSIE: Semiprojective Scales of Institutional Evaluation, Research in Higher Education, 1975, 3, 131-138.

Madron, T. W., Craig, J. R., and Mendel, R. M. Departmental morale as a function of the perceived performance of department heads. Research in Higher Education, 1976, 5 83-94.

Morgan, M. K. Male university attrition: A discriminant analysis: Research in Higher Education, 1974, 2, 281-290.

Pascarella, E. T., and Terenzini, P. T. Outcomes of the academic nonacademic college experience related to frequency of students' informal interaction with faculty. Proceedings of the 16th Annual Forum of the Association for Institutional Research, 1976, 27-33.

Perry, R. R. and Lind, D. A. Criteria warranted for evaluation of academic programs at the University of Toledo. Proceedings of the 16th Annual Forum of the Association for Institutional Research, 1976, 19-26.

Smart, J. C. Institutional goal congruence: A study of student, faculty, and administrator preferences. Research in Higher Education, 1975, 3, 285-297.

Smart, J. C., and Elton, C. F. Administrative roles of department chairmen. In J. Smart and J. Montgomery (Ed.s.), Examining departmental management. New Directions for Institutional Research (No. 10). San Francisco: Jossey-Bass, 1976, 39-60.

Tatsuoka, M. M. Multivariate Analysis: Techniques for Educational and Psychological Research. New York: Wiley, 1971.

Terenzini, P. T., and Pascarella, E. T. The relative importance of initial student characteristics and the freshman experience of college in voluntary attrition. Proceedings of the 17th Annual Forum of the Association for Institutional Research, 1977, 213-218. (a)

Terenzini, P. T., and Pascrella, E. T. Voluntary freshman attrition and patterns of social and academic integration in a university: A test of a conceptual model. Research in Higher Education, 1977, 6, 25-43. (b)

Warwick, P. V. Canonical correlation analysis. In N. Nie et al, SPSS: Statistical Package for the Social Sciences (2nd ed.). New York: McGraw-Hill, 1975.

Winer, B. J. Statistical principles in experimental design (2nd ed.). New York: McGraw-Hill, 1971.